Claims:

We claim:

1. An apparatus for supporting a biofilm in a liquid comprising:

a) a plurality of gas permeable hollow fibers, each hollow fiber having a lumen, an outer surface and an open end; and,

b) a header, the header having a cavity and a port open to the cavity,

wherein the hollow fibers extend from the header, with the outer surfaces of the open ends of the hollow fibers sealed to the header and the lumens of the hollow fibers communicating with the port through the cavity.

2. The apparatus of claim 1 wherein the hollow fibers have an outside diameter of 100 microns or less.

3. The apparatus of claim 1 wherein the hollow fibers have a hollow area of 10% or more, more preferably 30% or more.

4. The apparatus of claim 1 wherein the hollow area is 50% or less.

5. The apparatus of claim 1 wherein the hollow fibers are non-porous or dense walled.

6. The apparatus of claim 1 wherein the hollow fibers comprise polymethyl pentene.

7. The apparatus of claim 1 wherein the hollow fibers have a second end and are between 0.25 metres and 3.0 metres long.

8. The apparatus of claim 7 wherein the hollow fibers have a second end and are between 1.0 metres and 2.0 metres long.

9. The apparatus of claim 1 wherein the hollow fibers are arranged into groups.

10. The apparatus of claim 9 wherein the groups comprise between 24 and 96 hollow fibers.

11. The apparatus of claim 9 wherein the groups further comprise second fibers that are stronger than the hollow fibers.

12. The apparatus of claim 9 wherein the group is a tow of fibers.

13. The apparatus of claim 9 wherein the group is a thread, yarn or twisted fibers.

14. The apparatus of claim 1 wherein the hollow fibers are curled, crimped or undulating along their length.

15. The apparatus of claim 1 wherein the hollow fibers extend along their length generally in a first direction.

16. The apparatus of claim 15 further comprising third fibers extending along their length generally in a second direction, the second perpendicular to the first direction.

17. The apparatus of claim 16 wherein the third fibers and hollow fibers are intertwined.

18. The apparatus of claim 17 wherein the hollow fibers and third fibers form a fabric.

19. The apparatus of claim 18 wherein the fabric is generally continuous across the length of the hollow fibers.

20. The apparatus of claim 18 wherein the fabric extends over a portion of the length of the hollow fibers near their open ends and does not extend over a central portion of the length of the fibers.

21. The apparatus of claim 20 wherein the hollow fibers and third fibers are woven, knitted, stitched or warp knitted together over at least a portion of the length of the hollow fibers.

22. The apparatus of claim 1 wherein the hollow fibers have second open ends.

23. The apparatus of claim 22 wherein the second open ends of the hollow fibers are potted in a second header.

24. The apparatus of claim 23 wherein the second open ends communicate with a second port of the second header through a second cavity of the second header.

25. The apparatus of claim 23 wherein the header and the second header are spaced apart from each other and the hollow fibers are arranged into one or more flat sheets or generally parallel planar structures extending between the headers.

26. The apparatus of claim 25 wherein the flat sheets or planar structures are generally parallel to each other.

27. One or more of the apparatus of claim 25 wherein adjacent planar structures have a spacing between them of between 2 mm and 20 mm or, more preferably, of between 3 mm and 15 mm.

28. The apparatus of claim 23 wherein the first header and second header are held apart at a distance that applies a tensile force to the hollow fibers.

29. The apparatus of claim 25 further comprising spacers between the flat sheets or planar elements outside of the header.

30. The apparatus of claim 25 wherein the flat sheets or planar structures further comprise a rigid member extending between the headers.

31. The apparatus of claim 1 having a surface area for oxygen transfer to surface area of supported biofilm ratio of about 1.6 or more.

32. The apparatus of claim 31 having a surface area for oxygen transfer to surface area of supported biofilm ratio of about 2 or more.

33. The apparatus of claim 32 having a surface area for oxygen transfer to surface area of supported biofilm ratio of about 5 or more.

34. The apparatus of claim 33 having a surface area for oxygen transfer to surface area of supported biofilm ratio of about 1 or less.

35. The apparatus of claim 18 wherein the roughness of the fabric is between 0.1 and 2 mm.

36. A reactor comprising:

a) a tank for holding a liquid to be treated, the tank having an inlet and an outlet;

b) an apparatus according to claim 1; and,

c) a gas delivery system for providing a gas to the port.

37. The reactor of claim 36 further comprising an agitator or aerator adapted to agitate the liquid around the apparatus.

38. The reactor of claim 36 further comprising a chemical injection system for injecting chemicals into either the lumens of the hollow fibers or a part of the reactor in communication with the outer surfaces of the hollow fibers.

39. The reactor of claim 36 having a heater to heat either the gas provided to the port or the liquid held in the tank.

40. A multi-stage reactor having two or more reactors according to claim 36, the outlet of a first reactor connected to the inlet of a second reactor.

41. The multi-stage reactor of claim 40 wherein the first and second reactors are plug flow reactors, batch reactors or continuously stirred reactors.

42. The multi-stage reactor of claim 37 wherein the apparatus of the second reactor has a lower surface area for oxygen transfer to surface area of supported biofilm ratio than the apparatus of the first reactor.

43. The multi-stage reactor of claim 40 wherein the apparatus of the first reactor has a surface area for oxygen transfer to surface area of supported biofilm ratio between of 5 or more and the apparatus of the second reactor has a surface area for oxygen transfer to surface area of supported biofilm ratio of 5 or less.

44. The reactor or multi-stage reactor of claim 36 wherein the reactor(s) have a plurality of the apparatus arranged in parallel between the inlet and outlet.

45. The multi-stage reactor of claim 40 wherein the fibers of the apparatus of the first reactor are formed into a sheet along their entire length while the fibers of the apparatus of the second reactor are unsupported by perpendicular fibers over a portion of their length.

46. A process for treating a liquid comprising the steps of:

a) contacting an apparatus having a port in communication with one or more inner surfaces of a gas permeable biofilm support medium with the liquid; and,

b) providing a gas to the port of the apparatus, the gas permeating to outer surface(s) of the medium to support a biofilm growing on the outer surface(s).

47. The process of claim 46 wherein the liquid comprises wastewater.

48. The process of claim 46 wherein the gas comprises oxygen.

49. The process of claim 46 wherein the gas comprises hydrogen.

50. The process of claim 47 wherein the biofilm is maintained in an aerobic state adjacent the outer surface(s) and in an anoxic or anaerobic state adjacent the liquid.

51. The process of claim 46 wherein the liquid is contacted with the apparatus in a batch or continuous process.

52. The process of claim 46 wherein the liquid is generally continuously or intermittently stirred.

53. The process of claim 46 wherein the liquid moves past the outer surface(s) in a generally plug flow.

54. The process of claim 46 wherein the biofilm is maintained in a state of generally endogenous growth.

55. The process of claim 54 performed in a septic tank or shipboard system or to treat a wastewater taken generally directly from one or more houses or businesses or parts of a ship.

56. The process of claim 46 wherein the biofilm is maintained at a thickness between 0.05 mm and 2 mm, more preferably between 0.1 mm and 1 mm.

57. The process of claim 46 further comprising the steps of maintaining a least a portion of the biofilm so that its thickness alternately increases and decreases, the biofilm increasing in thickness over first periods of time and, between the first periods of time, reducing the thickness of the biofilm.

58. The process of claim 57 wherein the thickness of only a portion of the biofilm is reduced at a time.

59. The process of claim 57 wherein the thickness of the biofilm is reduced by air scouring or agitating at least a portion of the liquid.

60. The process of claim 57 wherein the thickness of the biofilm is reduced by contacting at least a portion of the biofilm with a second liquid containing worms or other animals which digest the biofilm.

61. The process of claim 57 wherein the thickness of the biofilm is reduced by applying ozone to at least a portion of the biofilm from the lemen side of the fibers or from the outside of the biofilm to oxidize the portion of the biofilm and then maintaining the biofilm to digest the oxidized portion.

62. The process of claim 61 wherein the thickness of the biofilm is reduced by introducing ozone gas into the port followed by supplying oxygen to the port.

63. The process of claim 57 wherein the thickness of the biofilm is reduced by supplying air to the port while the liquid is removed from contact with the biofilm or provided at a loading of less than 0.1 kg CODs per kg MLSS per day to digest the biofilm aerobically.

64. The process of claim 57 wherein the thickness of the biofilm is reduced by applying a control agent to at least a portion of the outer surface of the biofilm.

65. The process of claim 64 wherein the control agent is clean water.

66. The process of claim 64 wherein the control agent is heated clean water, preferably heated to between 40 and 60 C.

67. The process of claim 64 wherein the control agent is ozone gas.

68. The process of claim 64 wherein the control agent is an alkali solution with a pH between 8 and 13, more preferably between 9 and 11.

69. The process of claim 64 wherein the control agent is an acid with a pH between 1 and 6, more preferably between 3 and 4.

70. The process of claim 64 wherein the control agent is a second liquid and the second liquid is agitated or aerated while in contact with the biofilm.

71. The process of claim 64 wherein the biofilm is digested aerobically after the control agent is applied.

72. The process of claim 57 wherein the thickness of the biofilm is reduced by draining the liquid away from contact with the biofilm.

73. The process of claim 57 wherein the thickness of the biofilm is reduced by stopping or reducing the supply of oxygen to the port from time to time or periodically to create alternating aerobic and anoxic or anaerobic conditions in a portion of the biolfilm.

74. The process of claim 57 wherein the thickness of the biofilm is reduced by physically removing a portion of the biofilm.

75. The process of claim 74 wherein the biofilm is physically removed by spraying it with a third liquid or scraping it with a brush or scraper.

76. The process of claim 57 wherein the liquid is removed from a portion of the biofilm while the thickness of that portion of the biofilm is being reduced.

77. The process of claim 46 wherein the amount of oxygen supplied to the port is increased during a period of time when the CODs of the liquid is increased.

78. The process of claim 46 wherein the liquid is periodically removed from the biofilm and replaced with a fresh batch of liquid and the supply of the gas is continued while the liquid is being removed, while the biofilm is not in contact with the liquid or while a fresh batch of liquid is being replaced in contact with the biofilm.

79. The process of claim 46 wherein the liquid, after being treated, has less than 10 mg/L of suspended solids and less than 50 mg/L of CODs.

80. The process of claim 46 operated in a two stage process wherein the first stage of the process reduces the CODs of the liquid to less than 300 mg/L, more preferably to between 200 and 300 mg/L.

81. The process of claim 46 wherein the liquid, before treatment, has a CODs of 1000 mg/L or more and the apparatus has a surface area for gas transfer to surface area of attached biofilm of 1 or more, more preferably between 1 and 10.

82. The process of aclaim 46 wherein the liquid, before treatment, has a CODs of 1000 mg/L or less and the apparatus has a surface area for gas transfer to surface area of attached biofilm of between 0.2 and 2.5.

83. The process of claim 46 wherein the liquid, before treatment, has a CODs of 300 mg/L or less and the apparatus has a surface area for gas transfer to surface area of attached biofilm of 1 or less, more preferably between 0.1 and 1.

84. A method for cutting the ends of fibers in the apparatus of claim 18 comprising the steps of gluing a potting resin around the open or looped ends of a plurality of the fibers and then cutting through the resulting block of hardened resin and fibers.

85. A method of producing an apparatus according to claim 18 comprising the steps of and adhering spacers to the planar member(s) parallel to but displaced from the open ends of the hollow fibers, a first edge of the spacers being nearer the ends of the hollow fibers and a second edge of the spacers being farther from the ends of the hollow fibers, inserting the planar member(s) into a header cavity, and applying a potting resin over the second edge of the spacers extending from the planar member(s) to walls of the header cavity.

86. The process of claim 57 wherein the thickness of the biofilm is reduced at least every 10 days or after the biofilm has digested between 20 and 200 grams of CODs per square metre of biofilm area since the last reduction.

87. The process of any of claims 46 operated as a batch process having steps of draining the liquid from a tank containing the apparatus, the draining step further comprising a step of draining a first part of the liquid containing settled solids to a first treatment system and draining a second part of the liquid to a second treatment system.